Development of a Pelvic Phantom for Dose Verification in High Dose Rate (HDR) Brachytherapy

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ABSTRACT
High dose rate (HDR) brachytherapy in the treatment of cervix carcinoma has become popular, because it eliminated many of the problems with conventional brachytherapy. In order to improve clinical effectiveness with HDR brachytherapy, dose calculation algorithm, optimization procedures, and image registrations should be verified by comparing the dose distributions from a planning computer and those from a humanoid phantom irradiated. Therefore, the humanoid phantom should be designed such that the dose distributions could be quantitatively evaluated by utilizing the dosimeters with high spatial resolution. Therefore, the small size of thermoluminescent dosimeter (TLD) chips with the dimension of 1/8'' and film dosimetry with spatial resolution of <1mm used to measure the radiation dosages in the phantom. The humanoid phantom called a pelvic phantom is made of water and tissue-equivalent acrylic plates. In order to firmly hold the HDR applicators in the water phantom, the applicators are inserted into the grooves of the applicator supporters. The dose distributions around the applicators, such as Point A and B, can be measured by placing a series of TLD chips (TLD–to-TLD distance: 5mm) in three TLD holders, and placing three verification films in orthogonal planes.

Keywords: HDR brachytherapy, a pelvic phantom, TLD, film dosimetry

1. INTRODUCTION
HDR brachytherapy has gained more popularity because of simplicity to use, less treatment times, and its clinical effectiveness. Also, major advantage of using the HDR unit is to obtain optimum dose distributions to various geometrical shapes of tumors. The optimum dose distributions are automatically determined by commercial treatment planning computers. But the dose distributions are determined by several factors: (1) physical, (2) radiological parameters and (3) optimization algorithm [1]. Because of the three steps involved in the process, starting from imaging to treatment planning, dose delivery and radiation dose that the patient receives may not accurately match the planed dose. Therefore, overall accuracy of dose distributions should be investigated by correlating the dose distributions of a planning computer and those of measured radiation dose obtained from the pelvic phantom. In this paper, a new phantom was fabricated to verify the absolute and the relative dose distribution

2. MATERIALS AND METHODS
2.1. Materials
A pelvic phantom was designed to simulate the clinical setups of cervix cancers. In the radiological treatment of the cervix cancers, a standard applicator is commonly used with HDR units in most cancer clinics. Based upon the clinical experience from using low dose rate brachytherapy, the doses at the point A and B are commonly described to determine treatment times. Also, dose distributions are considered to determine proper tumor coverage. In addition to the point doses, the limiting factors using HDR units are the bladder and the rectum dose in order to minimize complications within acceptable ranges. The detailed description of the point A and B are given in literature [2].

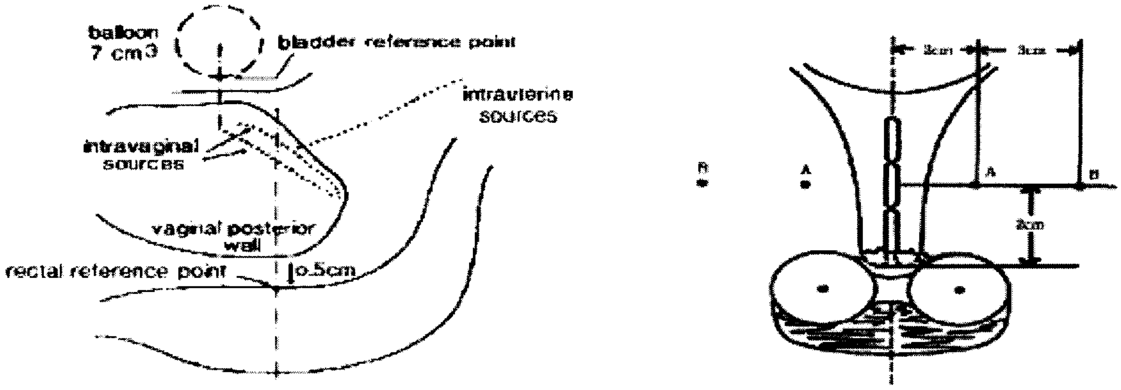

Fig.1. Determination of the points (a) Point of bladder and rectum point, (b) A and B point

The pelvic phantom should have two dosimetric techniques: absolute and relative doses. The absolute doses are measured with TLD (Thermoluminescent dosimeter), while the relative doses are with film dosimetry. In order to make the absolute dose measurements accurate, the pelvic phantom is fabricated utilizing tissue-equivalent acrylic plates and water. The acrylic plates with the electron density of 1.14 are used to firmly hold the applicators and TLD chips. Also, film dosimetry for relative dose distributions is used to investigate the dose distribution in three orthogonal planes. Kodak X-Omat (Kodak, USA) films are inserted into the pelvic phantom.

2.2. Methods

This pelvic phantom was fabricated to verify the dose calculation algorithm using TLD and film dosimetry. It is designed to insert TLD chips for absolute dosages and films in three orthogonal planes for relative dose distributions. Following treatment planning, the phantom was brought to the table of standard C-arm machine (model KXO-15E, TOSHIBA). For the localization purpose, the grid plate with cross patterns is placed on the top of the Image-Intensifier unit. Thus, AP and lateral films of the phantom with HDR applicators in the applicator holder (see the Figure 3. (c)) are taken and registered. The phantom is re-exposed to deliver the radiation dosages to the Point A or arbitrary points. And the films are placed in three orthogonal planes and exposed. The exposed films are scanned by using the film scanner (VIDAR). The scanned film is input to the computer for correlation with TLD dose to produce relative and absolute dose distributions.

2.3 Detailed Structures of the Phantom

The pelvic phantom consists of 5 pieces: an applicator holder, top and bottom applicator holder supporters, and two sets of film holder. A schematic diagram of the pelvic phantom is shown in fig.2. The applicator holder is used to firmly hold the HDR applicator. The top and bottom supporters simulate the bladder and rectum portion of a patient, also has three TLD holders for dose measurements and lead balls for geometrical landmarks. The film holders are used to place the verification film in three orthogonal planes for the verification of dose distributions. It contains 4 radiological fiduciary markers for the geometrical verification of the film. The supporters and film holders are made of 0.5cm thick acrylic plates and water in them.

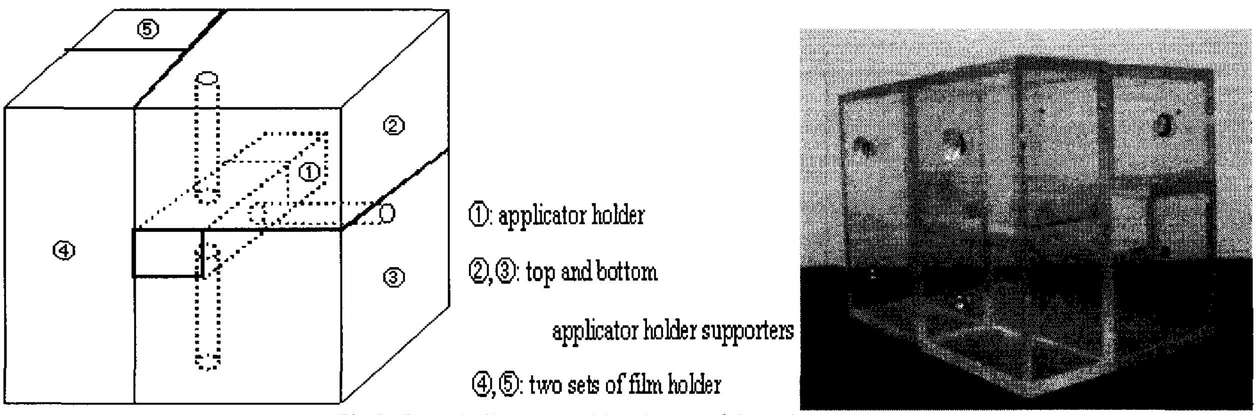

Fig.2. Overall diagram and its picture of the pelvic phantom

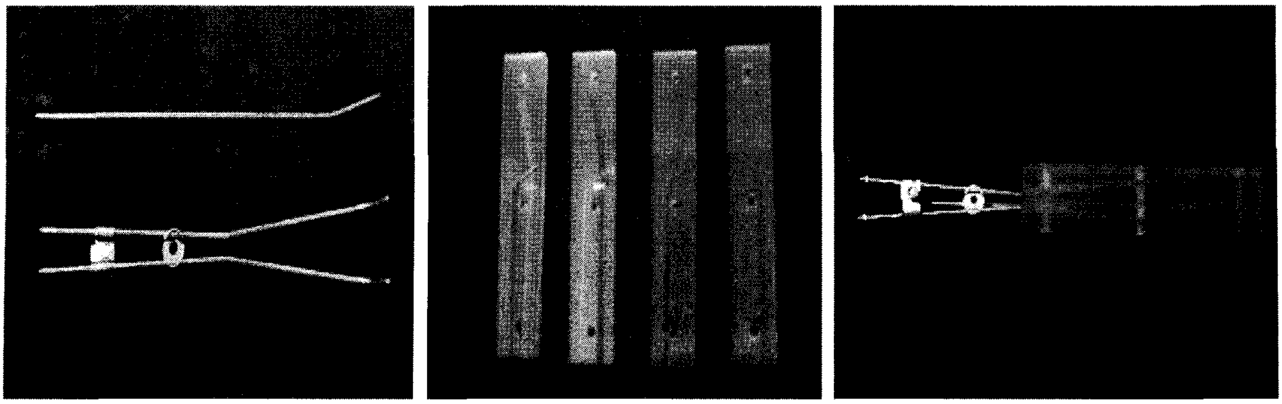

Fig. 3. Four pieces of acryl slit (a) Standard HDR applicator, (b) Sectional view of the holder, (c) HDR applicator in the holder

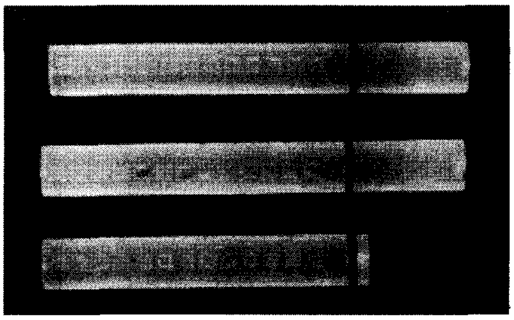

Fig.4. TLD holders of TLD chips for dose measurements and lead balls for geometrical landmarks

3. RESULT AND CONCLUSION

The pelvic phantom is assembled and shown the Figure 5. This pelvic phantom was fabricated to verifying accuracy of absolute, relative dose distribution in the treatment of cervix carcinoma. It could be a useful phantom to verify dose calculation algorithm and accuracy of image localization algorithm in high dose rate (HDR) planning computer. Also the phantom can be used to develop various treatment techniques in other treatment areas with minimum modifications. The dose verification with film dosimetry and TLD are under progress as a quality assurance (QA) tools in the Catholic University, Seoul, Korea. The discrepancy could be caused by uncertainties due to dose calculation model, optimization process, and the absorption and scattering of the HDR applicators.

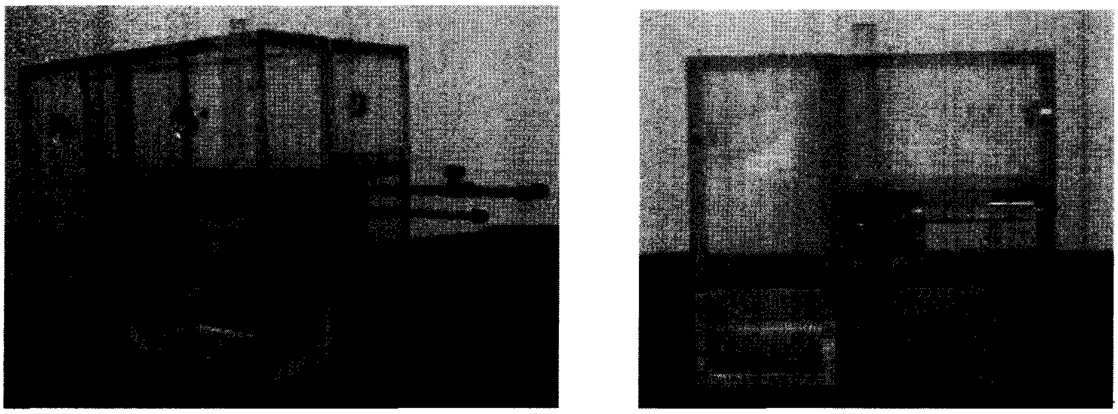

Fig. 5. Pelvic phantom (a) Side view, (b) bottom view

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